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ABSTRACT

Cost models representing equipment, services, software, and training needs are presented for evaluating the total cost of fully connecting K-12 schools to a national information infrastructure (NII). Analysis indicate that the baseline service required for connecting to the NII will cost $9.4 to $22.0 billion in one-time costs with annual maintenance costs of $1.8 billion to $4.6 billion or $212 to $501 in one-time installation costs and an ongoing annual cost of $40 to $105 per pupil respectively. Hardware is the most significant cost item for schools. PC expenditures represent most of the hardware costs, and costs for support of the network represent about one-third of all networking. Support and training together constitute 46 percent of the total costs of networking schools, and costs for telecommunications lines and services represent only 11 percent of the total costs. If all schools coordinate purchasing at the state level, cost savings will exceed $2 billion. If a nationwide program were instituted, potential savings would be $800 million to $1.8 billion. Free Internet connectivity would provide a reduction in total costs for school Internet connections between $150 million and $630 million. Financing for school networking remains to be adequately addressed. (Contains 13 references.) (GR)

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Technology and Cost Models for Connecting K-12 Schools to the National Information Infrastructure

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ABSTRACT

It is presumed that universal connection to the national information infrastructure (NII) will facilitate educational reform within schools and communities. Several developments suggest that this might be the case:

- The federal government is committed to have every classroom in the United States connected to the NII by the year 2000;
- A number of telephone and cable companies have announced plans to connect schools in their service areas at low or no cost;
- Modern, high-speed networks have been installed at a number of progressive, pioneering K-12 schools; and
- The Internet, a global network of networks, has grown rapidly, providing connections to an abundance of educational resources.

However, to date, there is relatively little known about the costs for connecting schools to the information infrastructure. Even if the exact costs are unknown, they are expected to be significant. To reduce these costs, a variety of approaches are being tried.

Some states have implemented the cost-saving program of purchasing telecommunications equipment and services for all schools in the state. For example, North Carolina has saved its schools 20 to 50 percent of the costs for certain items. Some states have passed legislation permitting the state public utility commission to set preferential or fixed intrastate rates for educational institutions.

Using a baseline of service required for connecting to the NII, there will be $9.4 billion to $22.0 billion in one-time costs with annual maintenance costs of $1.8 billion to $4.6 billion. At the per-pupil level, this is equivalent to $212 to $501 in one-time installation costs and an ongoing annual cost of $40 to $105.

Hardware is the most significant cost item for schools. However, most of this cost item is allocated for the purchase of PCs in the schools. The value of the PCs goes well beyond their use as networking devices. Therefore, the real costs for PC purchases should be allocated across other parts of the technology budget, and not only to the networking component. If this is done, then the hardware costs for connecting to the NII

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drop considerably.

Excluding PC expenditures, costs for support of the network represent about one-third of all networking. Support is a vital part of the successful implementation of a school network and its costs must be factored in to the budget. Support and training together constitute 46 percent of the total costs of networking schools. Costs for telecommunications lines and services represent only 11 percent of the total costs. This amount is lower than the costs assumed by much of the technology community, including the telecommunications service and equipment providers.

Our research suggests that a number of programs would have a significant impact on the total costs of connecting to the NII. If all schools coordinate purchasing at the state level, cost savings will exceed $2 billion. Colleges and universities often have the resources to provide technical support to K-12 schools. If a nationwide program were instituted, potential savings would be $800 million to $1.8 billion. If schools were given free Internet connectivity, the reduction in total annual costs for school Internet connections would be between $150 million and $630 million.

Finally, as the costs of networking schools are better understood, a new question arises: how will these costs be financed? Many states have programs to fund networking in schools. The federal government has a role, although it must become more flexible and coordinated. However, as Vice President Al Gore has continued to state, the NII will be built by the private sector. A number of states have initiated cooperative ventures between businesses and schools. An expansion of these programs may well be the key for successfully connecting K-12 schools to the NII.

INTRODUCTION

On January 11, 1994, Vice President Al Gore challenged the nation to "connect every classroom by the year 2000" to the national information infrastructure (NII). In testimony before Congress in May 1994, Secretary of Education Richard Riley said, "We may have to go a step further and provide our schools with free usage of the telecommunications lines that will connect school children and young people" to the NII. In an address at the Harvard Graduate School of Education, FCC Chairman Reed Hundt said that "if the Administration's challenge is met by everyone, education in this country will be reinvented, forever and for better." Universal connection to the NII, it is presumed, will facilitate educational reform within schools. However, to date, relatively little information has been available about the costs for connecting schools to the information infrastructure. This paper presents models for evaluating the total cost of full NII connectivity for schools through an engineering cost study of equipment, services, software, and training needs.

Cost Models of K-12 Networking

Five models for connecting schools to the NII are presented in the next section in order of increasing cost and power to describe the path that many schools may follow. A school will likely begin its connection through the low-cost dial-up option described in model one. As the school builds expertise and develops a need for greater capability, it will upgrade to a higher level of connectivity. It is not until the school acquires telecommunications infrastructure similar to model four that it is able to take advantage of many of the educational services and applications provided on the emerging NII. Model five presents the costs for putting a PC on the desktop of every student, with a high-speed connection to the Internet. Although this setup is not necessary for access to many of the coming NII services, it presents a model of systemic educational reform with information and networking technology.

These models are representations of the network technology used in schools. A level of complexity and detail is omitted from these models, but the simplicity is helpful because the models encompass broad cross sections of network and school configurations. The models provide a clearer view of the costs and choices for networking K-12 schools.

There are numerous ways to define a school network. The models presented below follow the Internet networking model, in which schools have digital data connections that transmit and receive bits of information. The models exclude both analog video point-to-point networks and voice networks including PBX, centrex, and voice-mail systems. Audio and video functions are possible in digital format over the Internet data network. However, many schools will require video and voice networks in addition to the data networks. The costs of these systems are important to consider but are not modeled in this paper.

It should be noted that although voice and video networks have been separated out from data networks in this paper, schools should not consider these three types of networks to be wholly distinct. Some schools have integrated their voice and video networks with the school data network. The sharing of resources among the multiple networks can be effective in providing significant cost savings. At a basic level, it must be understood that as a school installs a LAN and puts computer data connections in every classroom, there are minimal added costs to concurrently install other types of connections, including telephone lines.

Assumptions

The assumptions described below are the basis for determining the costs of networking schools. These assumptions are conservative but realistic, to ensure that the total costs are not underestimated.

Technology Standard for Connecting to the NII

As described by the Information Infrastructure Task Force (1994), the NII "promises every . . . school . . . in the nation access anywhere to voice, data, full-motion video, and multimedia applications. . . . Through the NII, students of all ages will use multimedia electronic libraries and museums containing text, images, video, music, simulations, and instructional software." In models four and five, the school has access to these NII services. The following requirements outline the needs for those models in order to have full connection to the NII:

- *A LAN within each school with connections to multiple machines in every classroom.* The power of the network is greatly enhanced as the number of access points increases throughout the school. A classroom with one connection is not conducive to use of network applications in a class of 20 or 30 students. Telecommunications technology will not be a tool for systemic educational reform until network connections are available throughout the school.

- *A connection from each school to a community hub.* From 2 to 10 schools should connect to a single hub, depending on the size of the schools. In most cases, the hub will reside at the school district office. However, in cases where there are many schools in a single district, the schools should be clustered into sets of four to six. Each of these school clusters will have a group hub, probably at the district office, which will contain the center of the network for those schools. The rationale for the use of this architecture is described below.

- *A connection between the school LAN and the district office hub.* With this configuration, every classroom has a connection not only to every other classroom in the school but also to the central school district office.

- *A connection from the school district office to a community-, state-, or nationwide wide area network (WAN).* This connection will allow all schools to connect to the WAN. The Internet is a good example of a WAN and is used throughout this report as a model and a precursor for the coming NII.

- *Sufficient bandwidth for these connections.* With a high-bandwidth connection, users in schools can make use of graphical applications (e.g., Mosaic) and limited video service (e.g., CU-SeeMe and MBONE). For most school districts, the minimum bandwidth, or bit-speed, that will support these services is 56,000 bits per second (56 kbps). Therefore, the connection between the school and the hub must be at or above this level. For the connection from the district office to the Internet, a higher bandwidth connection is necessary because all of the schools in the group connect to the Internet through this line. The suggested minimum bandwidth for this connection is 1,500,000 bits per second (1.5 Mbps), otherwise known as a T-1 line.

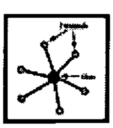
- *Symmetric, bidirectional access to the WAN/Internet.* It is important that the connection to a school allow information to flow both in and out of the school at the same rates. In this way, students can become both consumers and providers of information over the network.

- *Adequate remote dial-up facilities.* With a sufficient number of modems and phone lines, faculty, students, and parents can gain access to the school system remotely on weekends and after school hours.

- *Use of established and tested technologies.* Schools have benefited most from mature technologies that have been well tested in the marketplace. Use of cutting-edge technologies has not been as successful in schools due to the instability of the technologies and the large amount of resources required to support them. The models assume the use of mature technology and transmission media. Therefore, modern technologies such as wireless and hybrid fiber coaxial systems are not considered in this study. However, given the rapidity of technological change and marketplace evolution for networking products and services, wireless and cable alternatives should be evaluated in future research.

Each of the successive models progresses closer to this configuration. The first three models represent the schools and districts that have not reached this level of networking. It is not until the fourth model that these requirements have been incorporated. The fifth model continues on this path and exceeds the baseline requirements. It is assumed that some schools will traverse the path through each of the models to connect to the national information infrastructure.

Architecture of the District Network



The basic network architecture for these models follows the "star" network configuration as illustrated in Figure 1. This architecture is also used in the nationwide telephone network. In the telephone network, residential telephone lines in an area are directly connected to a single district office. In the school network, each school building is connected to the school central hub. In most cases, the district office will serve as the central hub. However, in cases where there are either few or large numbers of schools in one district, alternative sites must be chosen.

The rationale for adopting this architecture is that, when many schools are connected through a single hub, costs can be aggregated among the schools. This gives schools stronger purchasing power as equipment purchases are aggregated by the school district for volume discounts. It also allows schools to share resources—such as the data line to the Internet, training programs, and full-time support staff—that each school might not be able to afford individually. Therefore, there are costs both at the school and at the district level for networking schools across the country. The star network configuration for schools, utilizing a community or district hub, is recommended in Gargano and Wasley (1994) and in California Department of Education (1994).

Cost Areas

The cost models presented in this paper include four types of costs—hardware, training, support, and retrofitting. The items included in these categories are summarized below.

- *Hardware.* Wiring, router, server, PCs, including installation, maintenance, and servicing of the hardware and telecommunications lines.
- *Training.* Training of teachers and other school staff to use the network.
- *Support.* Technical support of the network.
- *Retrofitting.* Modifications to the school facility to accommodate the telecommunications infrastructure. This may include costs for asbestos removal (where applicable); installation of electrical systems, climate control systems, and added security (locks, alarms, etc.); and renovation of buildings to accommodate network installation and operation.

The following cost area is not included in the models:

- *Educational software.* There are "freeware" versions of many popular Internet applications. However, other educational software may be desired by particular schools. The costs for this software may be high, but they are not included in the models. Further economic analysis of software costs and their evolution in the network scenarios analyzed below is required.

Instructional Use of the Network

It is likely that the type of technology model deployed in the school will greatly affect the use of the network and the educational benefits obtained. A school with multiple networked PCs in every classroom (model four) will reap greater educational benefits from the network than a school with a single PC and modem (model one). Similarly, video and graphical applications (e.g., Mosaic and CU-SeeMe), available in models four and five, add educational value to the text-based applications available in the lower-end models. However, there has not yet been a quantitative analysis of the educational benefits associated with each particular model. This paper is concerned exclusively with the costs for the various network models. Study to determine the educational benefits of various K-12 network models is also needed. When the educational benefits are quantified, they should be compared to the costs outlined in this paper. The synthesis of these studies will generate a cost-benefit curve for connecting schools to the network. That information is vital for determining national policy on connecting schools to the NII.

School Characteristics

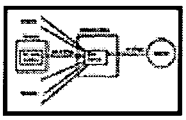
The models described are based on a "typical" school and school district, as defined by the U.S. Department of Education (1993), and represent the average costs of all U.S. schools and school districts. Many schools will differ in significant ways from the "typical" school and will therefore face somewhat different costs from those presented in the models.

Size of School. The average school has about 518 students and twenty classrooms. It employs 27 teachers and 25 other school staff. The average number of schools in a school district is about six. (These numbers are based on a national enrollment of approximately 44 million students in 85,000 public schools in 15,000 school districts.)

Existing Equipment. According to Anderson (1993), as of 1992 there was an average of 23 computers per school at the elementary and middle school levels, and 47 computers per school at the secondary school level. About 15 percent of these machines, or three to seven machines per school, are capable of running the network protocol (TCP/IP) to access the Internet. During the 3 years from 1989 until 1992, the number of computers in schools grew by 50 percent. Given the increasing growth rate of computers in the market, it is safe to assume that the growth rate of computers in these schools has exceeded 50 percent over the past 2 years. Given these assumptions, in an average school there are at least seven PCs capable of running graphical Internet applications (e.g., Mosaic). This number of PCs is sufficient for the first two models, but it is not sufficient for establishing multiple connections in every classroom throughout the school. Therefore, for models three, four, and five, there is a line-item cost for purchasing additional PCs.

COST MODELS

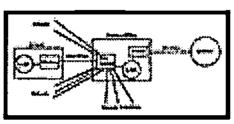
Single-PC Dial-up (Model One)



The single-PC dial-up model (Figure 2) represents the most basic connectivity option for a school. The school has no internal LAN. There is a single connection to the district office over a modem and standard phone line. Only one user may use the connection at any time. Since the system is limited, only a few teachers in the school require training. Users of the system will be able to use text-based applications over the Internet (e.g., e-mail, Telnet, Gopher), but will have no real-time access to video or graphics.

Model one is the lowest-cost option for schools. Many of the services and benefits envisioned for the NII will not be widely accessible in schools using this model of connectivity. Table 1 lists the cost items associated with the single-PC dial-up model.

LAN With Shared Modem (Model Two)

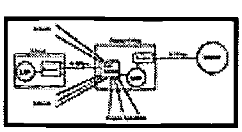


The primary difference between model two (Figure 3) and model one is the existence of a LAN within the school. By connecting the modem to the LAN, every computer on the network has access to the Internet. However, this model supports only a few users at a time, since it is limited by the number of phone lines going out of the school. As in model one, users of the system can use text-based applications over the Internet (e.g., e-mail, Telnet, Gopher) but have no real-time access to video or graphics.

In model two, there is the added cost for a LAN. This model assumes the use of copper wire (category 5) as the medium for the network since it is the most affordable and scaleable option for schools in 1994. The costs for the wiring and network cards run $100 to $150 per PC connected. Including the costs for the accompanying hardware and labor, the costs per PC are $400 to $500. Therefore, for a school with 60 to 100 connected PCs (3 to 5 PCs per classroom @ 20 classrooms), the total LAN costs are $20,000 to $55,000.

Model two is another low-cost option for schools. However, many of the services and benefits envisioned for the NII are still not widely accessible in this model. Table 2 lists the cost items associated with this model.

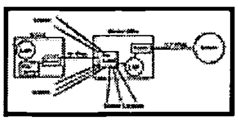
LAN with Router (Model Three)



The primary difference between model three (Figure 4) and model two is a router in place of the modem. With the router, multiple users of the LAN may access the Internet concurrently. Just as in the first two models, users of the system are able to use text-based applications over the Internet (e.g., e-mail, Telnet, Gopher) but have no real-time access to video or graphics.

Since the router allows multiple users of the system, there is an opportunity to expand the entire network infrastructure. With this infrastructure, it is reasonable to support one PC in every classroom. Therefore, there is a requirement to purchase 15 additional PCs for the average school to use in addition to its small initial stock of TCP/IP-compatible machines. It is assumed that the purchasing of these PCs is done at the district level to negotiate better rates ($1,000 to $2,000 per PC). Support and training costs are higher since there are additional users of the system. There are additional dial-up lines required to accommodate remote access, as well as significant retrofitting costs for the electrical system, climate control system, and enhanced security. Table 3 gives a line item summary of the costs associated with model three.

LAN with Local Server and Dedicated Line (Model Four)

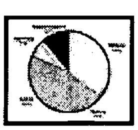


The primary difference between model four (Figure 5) and model three is the existence of a file server at the school. The on-site server allows much of the information to reside locally at the school instead of at the district office. This feature provides better performance since much of the information does not need to be fetched over the network. Additionally, the local server allows school administrators to exercise greater control over the information that flows in and out of the school. Higher-speed links from the school enable the use of limited video, graphical, and text-based network applications.

In model four, virtually the entire school is supported on the network. As a result, the training program is extensive and the support team is well staffed. The costs of the connection to the Internet are also higher due to the larger bandwidth connection. There are significant retrofitting costs for the electrical system, climate control system, and better security. Table 4 lists the cost items associated with this model.

The costs associated with using model four are indicative of the costs of connecting K-12 schools across the country to the NII. These numbers indicate that there will be $9.4 billion to $22.0 billion in one-time costs, with annual maintenance costs of $1.8 billion to $4.6 billion. At the per-pupil level, this is equivalent to $212 to $501 in onetime installation costs and an ongoing annual cost of $40 to $105.

In this model, hardware is the most significant cost item for schools. However, most of this cost item is allocated for the purchase of PCs in the schools. The value of the PCs goes well beyond their use as networking devices. Therefore, the real costs for PC purchases should be allocated across other parts of the technology budget, and not only to the networking component. If this is done, then the hardware costs for connecting to the NII drop considerably.

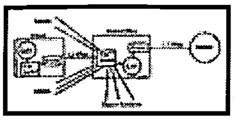


If the high start-up costs are amortized equally over a 5-year period, then the breakdown of costs during the first 5 years, excluding PC purchases, is as shown in Figure 6.

Costs for support of the network represent about one-third of all networking costs in model four. Support is a vital part of the successful implementation of a school network and its costs must be factored into the budget. Support and training together account for 46 percent of the total costs of networking schools.

Finally, it is important to note that the costs for telecommunications lines and services represent only 11 percent of the total costs. This amount is lower than the costs assumed by much of the technology community, including the telecommunications service and equipment providers.

Ubiquitous LAN with Local Server and High-Speed Line



Model five (Figure 7) represents a full, ubiquitous connection to the NII. In this model, there is a PC on the desktop of every student and teacher. There is a high-bandwidth connection to the school to support large numbers of concurrent users of the system. This model supports the full suite of text, audio, graphical, and video applications available over the Internet.

In model five, the entire school is supported on the network. A large portion of the costs for this model is the expenditure for PCs on every desktop. Assuming 500 students, there is a need to purchase 450 new PCs. Since the network is ubiquitous, the training program is extensive and the support team is well staffed. The costs of the connection to the Internet are also higher because of the high-speed line going into the school. The file server is larger than model four's server to accommodate the large number of networked PCs. The dial-up system is larger in order to allow many students, teachers, and parents to access the system remotely. The retrofitting costs are substantial because extensive electrical work must be performed in the average school to accommodate the hundreds of new PCs. In addition, the school in model five must make expenditures on air conditioners and security locks to protect the new equipment. Table 5 lists the cost items associated with this model.

COST COMPARISON OF MODELS

U.S. expenditures on K-12 education in 1992 93 totaled $280 billion. Total onetime costs for model four represent 3 to 7 percent of total national educational expenditures. The ongoing annual costs represent between 0.6 and 1.6 percent of total national educational expenditures. For model five, the costs are more significant, with one-time costs representing 18 to 41 percent of total national educational expenditures.

The models with advanced connectivity include significant equipment and training costs, which may be beneficial for educational purposes other than network uses. If these costs are accounted for separately, the difference in costs between models four and five will not be as significant as those presented here.

Table 6 summarizes the associated range of costs for the various technology models.

POTENTIAL IMPACT OF COST-REDUCTION INITIATIVES

Much more can be done by the government and the private sector to significantly mitigate costs schools face to connect to the NII. This section examines some possible programs and their impact on costs to schools.

In determining the costs savings from programs supporting connection to the NII, it is imperative to define the model of the NII. In this paper, the baseline model for NII access is a school with a LAN, a local server, and a dedicated line to the district hub. This is the fourth model as described above. The costs for this model are summarized in Table 7.

Based on the costs listed in Table 7, we have estimated the potential total cost savings for U.S. schools from various programs.

1. *Preferential telecommunications tariff rates are instituted for schools.* Some state utility commissions have instituted preferential telecommunications rates for educational institutions. These rates are applicable only for intrastate traffic. For interstate traffic, the tariffs set by the Federal Communications Commission are in effect. Currently, these tariffs have no preferential rates for educational institutions. The amount of money that schools will save will depend on the amount of discount if preferential rates are adopted. The following numbers represent the estimated savings with educational discounts of 30 percent and 60 percent.

- 30 percent reduction—$39 million to $150 million (annual)

  Estimated savings: $89 million to $218 million (onetime)

- 60 percent reduction—$78 million to $300 million (annual)

  Estimated savings: $179 million to $435 million (onetime)

2. *All information technology purchasing is done at the state level.* When states are involved in purchasing information technology, schools may secure better prices due to volume discounts. Schools in North Carolina, for example, have enjoyed discounts of 20 to 50 percent for hardware and labor costs. The following figures indicate the possible cost savings across all 50 states, based on an average 30 percent discount.

Estimated savings: $1.9 billion to $4.1 billion (onetime); $45 million to $189 million (annual)

3. *Universities or other institutions provide technical support to schools.* Universities can also play a role in providing technical support to K-12 schools. Many universities have already undertaken such a project and have provided network support to a number of K-12 schools in their area. With such a program, schools will still require some dedicated support staff. However, it is assumed that schools will be able to function with 80 percent less technical support staff than would be required without university support.

Estimated savings: $790 million to $1.8 billion (onetime)

4. *Teachers are trained on their own time.* In the models, a large portion of the training costs are dedicated either to paying substitute teachers to cover for teachers in training, or to paying teachers to be trained after school hours. If teachers agree to attend classes on their own time, there will be costs only for the trainer.

Estimated savings: $0 to $1.5 billion (onetime); $0 to $300 million (annual)

5. *The LAN is installed by volunteers.* In the models, 65 percent of the costs for installing the LAN are dedicated to labor. If schools can do this work with volunteers, then the cost savings are significant. As an example, Val Verde Unified School District in California laid its wires with volunteers from parents and community members. If such groups provide labor at no cost to schools, schools will reap significant savings.

Estimated savings: $1.1 billion to $3.1 billion (onetime)

6. *Personal computers are donated to schools.* In the models, there is a need to purchase a significant number of PCs to provide four to five connections to the network in every classroom. The costs for these PCs can be offset by donations of new machines from PC manufacturers. It is also possible for large corporations to donate these computers to schools. However, the schools will need fairly modern machines to run networking software. The success of a donation program is dependent on the quality of the equipment donated. Donations of obsolete or incompatible equipment may be costly to schools.

Estimated savings: $5.1 billion to $10.2 billion (onetime)

7. *Network routing equipment is donated to schools.* This program is similar to the PC donation program. The savings are lower since the routing equipment is less expensive.

Estimated savings: $221 million to $425 million (onetime)

8. *Network servers are donated to schools.* This program is similar to the PC donation and router donation programs.

Estimated savings: $370 million to $1.5 billion (onetime)

9. *Internet connectivity is made free to schools.* There are great potential cost savings if schools are given Internet access at no cost. This plan could be arranged either by provision from an Internet service provider or from a local university or community college that has its own Internet connection.

Estimated savings: $150 million to $630 million (annual)

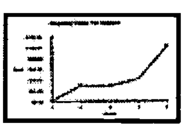
Table 8 summarizes the potential savings for U.S. schools nationwide from each of the possible programs.

CONCLUSIONS

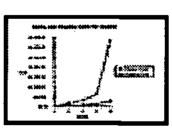
With a clearer picture of the costs for connecting schools to the NII, a number of conclusions may be drawn:

The costs to network a school are complex. It is not simple to estimate the costs for connecting a particular school to the network. The costs for most schools will fall into a bounded range, but each particular school will vary greatly, depending on its individual needs and characteristics. Although this analysis puts bounds on the cost figures, the numbers are rough estimates at best.

The cost of the network hardware is only a small fraction of the overall costs for connecting to the NII. Initial training and retrofitting are the largest onetime costs for starting connectivity to the network. The costs for the wiring and equipment are typically not as high. Support of the network is the largest ongoing annual cost that schools must face.



There are two major jumps in the costs to network a school. The jumps occur in the transitions from model 1 to model 2 and from model 4 to model 5, as illustrated in Figure 8. The first jump in cost occurs when the school installs a LAN. At that point the school and district must pay to have the network installed ($20,000 to $55,000 per school) and employ full-time network support staff ($60,000 to $150,000 per school district). The second jump occurs if and when the school decides to purchase computers for all students to use. The number of networkable PCs in 1994 is inadequate for most schools; hundreds of thousands of dollars would be needed to provide multiple PCs in every classroom. Also, many schools will need major electrical work (possibly exceeding $100,000 each) to support the increased number of PCs in the school. In the intermediate stages between these jumps, the costs are incremental and relatively small.



The start-up costs for connection to the network increase at a faster rate than the annual ongoing costs as the complexity of network connection increases. In the less complex models, the onetime start-up costs are 2 to 3 times the annual ongoing costs of the network. However, for the more complex models (models four and five,) the onetime costs are 5 to 15 times the costs to start connecting to the network. The differences are illustrated in Figure 9. The divergence indicates that the most significant cost hurdle that a school will face is the initial investment in the network and computers. Dispensers of educational funding should be aware of this circumstance, so that they can help schools overcome the initial barrier. Schools should be given flexibility to amortize initial costs, to spread out the burden over a number of years.

Costs are significantly reduced when aggregated at the district and state levels. Schools stand to save a lot of money by pooling resources and purchasing power with other schools at the district and state levels. When schools share a high-speed data link, or support staff, the per-school costs drop considerably. Schools in North Carolina and Kentucky have saved 20 to 50 percent by purchasing services and equipment at the state level.

Further research on the costs of wireless and cable Internet access methods for schools is recommended to elucidate the costs and benefits of these approaches. In addition, the issue of software and equipment cost accounting requires further analysis. This preliminary assessment of the costs of connecting schools to the NII is intended as a point of departure for analysis of these and other more detailed models of NII connectivity.

NOTE: Russell I. Rothstein is a research assistant and Lee McKnight is a principal research associate with the MIT Research Program on Communications Policy. This paper is based on a report prepared when Russell Rothstein was a visiting researcher at the Office of Educational Technology in the U.S. Department of Education in 1994. Further work was supported by ARPA contract N00174-93-C-0036 and NSF grant NCR-9307548 (Networked Multimedia Information Services). The invaluable help of Linda Roberts, U.S. Department of Education, and Joseph Bailey, Thomas Lee, and Sharon Gillett, MIT Research Program on Communications Policy, is acknowledged.

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